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How Much Internalization of Nuclear Risk Through Liability Insurance?

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Abstract

An important source of conflict surrounding nuclear energy is that with a very small probability, a large-scale nuclear accident may occur. One way to internalize the financial risks associated with such an accident is through mandatory liability insurance. This paper presents estimates of the willingness to pay for increased financial security provided by an extension of coverage, based on the 'stated choice' approach. A Swiss citizen with median characteristics may be willing to pay 0.08 cents per kwh to increase coverage beyond the current CHF 0.7 bn. (US$ 0.47 bn.). Marginal willingness to pay declines with higher coverage but exceeds marginal cost at least up to a coverage of CHF 4 bn. (US$ 2.7 bn.). An extension of nuclear liability insurance coverage therefore may be efficiency-enhancing.

1 Introduction

Nuclear power plants provoke conflicts in many countries. While many voters and politicians are precommitted on this issue, others will gauge the advantages and disadvantages of the nuclear option. On the downside, an important consideration is that with a very small probability, an accident causing billions of Dollars of damage may occur.

How important to Swiss citizens is relief from the financial consequences of a severe nuclear accident? This paper purports to answer this question. Relief could be achieved through the extension of the liability insurance coverage mandated to nuclear power plant operators. The current insurance

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coverage of CHF 0.7 bn. (approx. US$ 0.47 bn. at 2002 exchange rates) written by private insurers will hardly be sufficient to compensate the victims of an accident. However, an extension of coverage will result in a higher price for nuclear power. Therefore, determining the importance accorded to more comprehensive relief from the financial consequences of a severe nuclear accident amounts to estimating the increase in the price of electricity that would be accepted by consumers in return for extended liability coverage to be bought by plant operators.

From the outset, two clarifications are in order. First, the risk to be considered needs to be defined. In the production process of nuclear energy, at least ten stages can be identified, each with its proper risks (Hirschberg, Spiekerman and Dones (1998)). This paper deals exclusively with the risks of nuclear energy produced in Switzerland. Second, focus is exclusively on mandatory liability insurance as an instrument for risk internalization. The many norms that govern the production of nuclear power, monitored by the Swiss Nuclear Safety Inspectorate (HSK), are simply taken as given. However this regulation in combination with the legal norm of liability still leaves room for what Shavell (1984), Shavell (1986) calls the judgement proof problem. The judgement proof problem consists of the possibility that nuclear power plant operators may fail to pay compensation for the damage caused, due to lack of assets. As shown by Shavell, mandatory liability insurance serves to avoid this shortcoming. This finding justifies considering mandatory liability insurance as an instrument of nuclear risk internalization.

This paper is structured as follows. In section 2 the 'stated choice' alternative to the more conventional 'contingent valuation' method for eliciting willingness to pay (WTP) is described and its use in the present context justified. Section 3 contains details concerning experimental design of a survey designed to measure WTP for improved financial security in the context of a nuclear accident. The econometric analysis follows in section 4, where the WTP estimates are subjected to several tests. Section 5 presents a summary and conclusions.

2 Determining Willingness to Pay Through 'Stated Choice'

For goods and services traded on markets, there is no need to measure willingness to pay (WTP). By accepting a price the customer reveals that his WTP is at least as high as the price. The safety of nuclear power plants is not yet traded on markets (though it is possible to think of nuke-bonds which mature in case of a prespecified accident). Neither do insurance contracts against nuclear risks exist which would reveal potential victims' willingness to pay for nuclear safety.

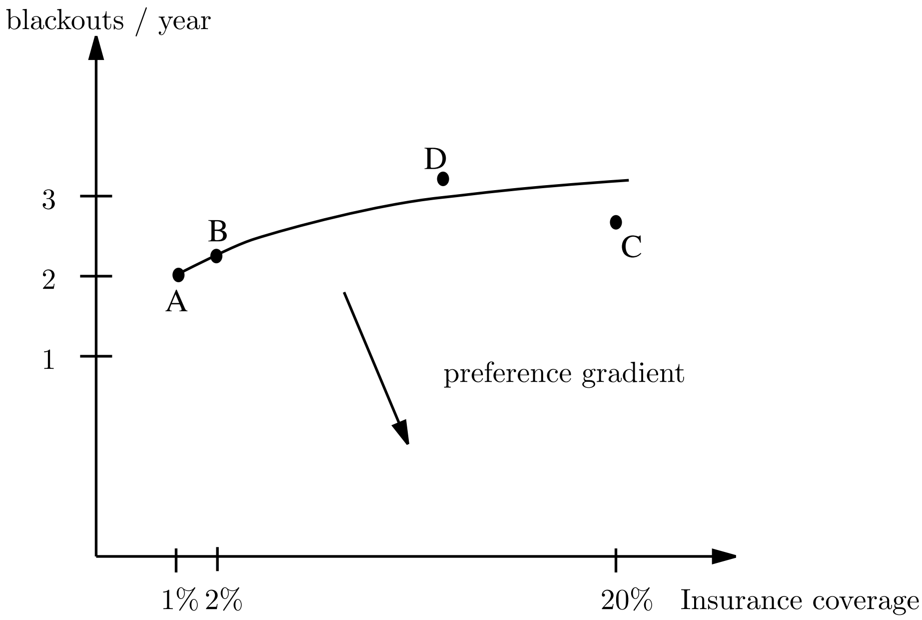

Figure 1: Trading off different product attributes.

Earlier attempts to measure WTP for nonmarket goods used the contingent valuation method (see e.g. Mitchell (1989) and Hausman (1993)). In the present context, respondents would have to state the maximum amount per kwh they would be prepared to pay for the increased financial security achieved by an extension of mandatory liability insurance. The difficulty with this direct approach is that in real life people hardly ever ask themselves such questions. Rather, they compare the attributes of a good and its price and then decide to buy it or not.

The 'stated choice' approach, developed by Louviere and Hensher (1982), seeks to simulate this every day decision making. Its basic assumption is that individuals derive utility from the attributes of products and are willing to trade them off against each other (Lancaster 1966). In the present context, the 'stated choice' method allows individuals to choose among different types of electricity. During the decision process, the attributes (among them price) of electricity are traded off against each other. By observing several similar decisions it is possible to estimate how much income (through higher electricity prices) respondents are ready to give up in return for extended insurance coverage.

This is illustrated in figure 1. Utility increases with insurance coverage in the event of an accident (as percent of maximum possible loss) and decreases with the average number of power blackouts; both attributes were found to be relevant to the persons interviewed (see section 3). Assume that the status quo is given by combination A (1% insurance coverage, 2 blackouts/year). Point B indicates that the individual is willing to accept a slightly higher number of blackouts if insurance coverage is raised to 2%. The corresponding sacrifice in terms of security of supply is the marginal WTP for an increased insurance coverage.

Now participants in the experiment are asked to evaluate additional combinations, for example point C. If C is accepted, then the individual's indifference curve must lie above C. Next, if point D is rejected, it must lie below D. Proceeding in this manner, it is possible to approximate the indifference curve. Finally, the marginal willingness to pay measured in money terms (MWP) can be estimated in the same way, by introducing the increase in the price of electricity as an additional product attribute. The corresponding increase in the outlay on electricity is a sacrifice of income which would otherwise be available for spending on other goods.

Summing up, the experimenter is not limited to varying only price and insurance coverage but can introduce other attributes that influence real life decisions concerning electricity. Failing this, he runs the risk of causing respondents to associate with variations in price or insurance coverage attributes not explicitly included in the experiment (and therefore assumed as fixed).

3 Experimental Design

In the context of a stated choice experiment several issues must be addressed. What product attributes are to be included? How many levels should be distinguished in an attribute (continnous representation being impossible)? Which functional form of the utility function should be assumed? An extensive literature is devoted to these and other issues (see e.g. Louviere, Hensher and Swait (2000) and Hedayat, Sloane and Stufken (1999)).

First of all, the relevant attributes of electric power need to be identified. Their number must be kept low for the decision problem to remain manageable. In a separate survey, approximately 500 persons were asked in spring 2001 to rate 15 different attributes, assigning them ranks between 1 (not important) and 10 (very important). Among the most important were: secure and sustainable waste disposal (9.26), size of area exposed to hazard (8.91), reliability (low frequency of blackouts) (8.68), financial compensation of the victims in case of an accident (8.78), and average price per kwh (7.69).

Next, levels have to be assigned to attributes. Again they must be few in number in order to avoid long interviews. But then, the levels must reach sufficiently extreme values to cause respondents to switch from "accept" to "reject" and vice versa.

To test the questionnaire, six persons were interviewed in a first pretest.

	Levels	Unit	Status quo
Price	0; 10; 30; 60	percent	0
Blackouts	2; 14	numb./year	2
Waste	unresolved problems; no unresolved problems	–	unresolved problems
Maximum loss[a]	0.1, 10, 100, 200	CHF bn.	200
(per houshold)[b]	(35; 3,500; 35,000; 70,000)	(CHF/HH)	(70,000)
Coverage[c]	1; 20; 50; 100	percent	1

[a] Values in US$ bn: 0.065; 6.5; 65; 130

[b] Maximum loss in US$ per household: 21; 2,100; 21'000; 42,000 (at 2002 exchange rates)

[c] Coverage in percent of loss

Table 1: Levels of characteristics.

Without exception they understood the questions and were able to process the 14 choice scenarios without problems. However, the attribute 'insurance coverage' was regarded as relatively unimportant.

A second pretest comprising 20 persons was conducted, with the maximum price boosted to 60 percent in order to induce a sufficient frequency of rejected scenarios (compared to the status quo). The most important attribute was again safe waste disposal, this time followed by insurance coverage and price.

The attributes and their levels used in the final survey are displayed in table 1.

The attribute 'Price' is the percentage increase caused by the extension of liability insurance coverage over the status quo. To obtain an absolute value for willingness to pay (WTP), this value was multiplied by the annual electricity bill as indicated by respondents.

The attribute 'Blackouts' indicates if the scenario considered has a high incidence of blackouts (14 per year, coded 1) or a low incidence (2 per year, coded 0). It is a proxi of service reliability.

Since 'Waste' was an important attribute in both pretests, it had to be included in the final experiment. This variable takes on two values: Either there are unresolved problems with waste disposal (=1), or there are no unresolved problems with waste disposal (=0).

'Maximum loss' indicates that electricity generation may cause damage amounting to e.g. CHF 100 bn. (appr. US$ 65 bn.) in the event of an accident. In order to make this amount more comprehensible, it was also expressed as an average per household.

'Coverage' indicates the part of maximum loss which would be covered by liability insurance.

Note that the probability of an accident is not among the product attributes. This has the advantage of easing the burden on the cognitive capabilities of respondents. As is well known, most people have difficulties

Decision No. 4209		
	Type A power	**Type B power**
Price	A kilowatthour costs the same as today	A kilowatthour is 60 percent more expensive than today
Blackouts	2 blackouts per year on average	2 blackouts per year on average
Waste	There are unresolved problems with waste disposal	There are no unresolved problems with waste disposal
Damage	A large scale accident can cause losses up to a maximum of Swiss francs 200 bn. (This amounts to Swiss francs 70,000 per household on average)	A large scale accident can cause losses up to a maximum of Swiss francs 100 mn. (This amounts to Swiss francs 35 per household on average)
Insurance Coverage	1 percent of this maximum damage is covered	100 percent of this maximum damage is covered
Your Choice	☐ Type A	☐ Type B
	☐ cannot decide	

Figure 2: Example of a choice scenario.

dealing with small probabilities (Starmer 2000). As a substitute, the probability estimates of experts were reported in the questionnaire, and respondents were asked to mark their own subjective estimates of the probability of a severe nuclear accident. In this way, the probability of an accident is held constant throughout the experiment, preventing it from being correlated with the attribute maximum loss (this would result in a biased estimate of the corresponding coefficient in econometric estimation). At the same time, this still permits to answer the question of wether a heightened perception of the loss probability influences the marginal willingness to pay for increased financial security.

Figure 2 shows one of the choice scenarios. Type A power is always associated with the status quo scenario to simplify the decision making.

Nevertheless, 20 percent of respondents reported difficulties with the questionnaire. Roughly 73 percent stated they considered one of the attributes to be of overriding importance, which could be interpreted as an indication of lexicographic preferences. However, the econometric analysis failed to produce evidence suggesting that these individuals traded off attributes less frequently or less consistently.

4 Econometric Analysis

4.1 Data

Face to face interviews were performed in the German speaking part of Switzerland during September and October 2001. With 391 persons evaluating 14 out of a total of 42 choice scenarios, a total of $5,474$ decisions were recorded. Respondents who felt unable to decide could always choose the option "not able to decide". This served to prevent choices at random by individuals who in fact were indifferent or unable to decide.

In a total of 819 cases (15 percent), no choice was stated, resulting in $4,655$ usable observations. Only 90 percent of these ($4,154$) were used for estimation, while 10 percent were put aside for an out of sample test (section 4.5). In 27 percent of choices, the status quo was preferred.

4.2 Theoretical Background and Specification

No attempt was made to anchor specification in expected utility theory in view of its lack of validity for small probability – high consequence risks (Starmer 2000).

Instead a second-order Taylor approximation of a general utility function in the retained attributes is used. To allow for heterogeneous preferences, socioeconomic characteristics of the respondents are interacted with income net of electricity outlay, in accordance with the standard procedure (Johnson and Desvousges 1997).

For individual i and power type j the following model is assumed

$$U_{ij} = \beta X_j + \gamma_1 z_i \cdot (m_i - P_{ij}) + \gamma_2 z_i \cdot (m_i - P_{ij})^2 \ ,$$

where X_j includes all linear, quadratic and mixed terms of electricity attributes, including price (P_{ij}). z_i denotes the vector of socioeconomic variables, m_i denotes income and β, γ_1 and γ_2 are to be estimated.

According to the random utility model (McFadden 2001), the respondent evaluates the utility of the two scenarios and chooses the one with the higher utility. If "A" denotes the attribute values of the status quo scenario, then individual i chooses the alternative (B) of choice set j if

$$\beta(X_{B_j} - X_{A_j}) + \gamma_1 z_i (P_{iB_j} - P_{iA_j}) + \gamma_2 z_i (P^2_{iB_j} - P^2_{iA_j}) - 2\gamma_2 z_i m_i (P_{iB_j} - P_{iA_j})$$
$$+\eta_i + \epsilon_{ij} > 0 \ .$$

The error term appearing in this comparision has an individual specific (η_i) and a general component (ϵ_{ij}) that also varies with the choice set presented. The two components are assumed to conform to the usual random effects specification (Greene 1997, ch. 14), with $\rho = var(\eta_i)/var(\eta_i + \epsilon_{ij})$.

Since almost half of the interviewed persons did not reveal their income, the term m_i is neglected in the estimation. Instead subsamples are created (high income, low income, income not revealed) to allow for income differences.

The dependent variable y_{ij} (choice of power type B) is given by

$$y_{ij} = \begin{cases} 1, \text{ if} \\ \beta(X_{B_j} - X_{A_j}) + \gamma_1 z_i(P_{iB_j} - P_{iA_j}) + \gamma_2 z_i(P^2_{iB_j} - P^2_{iA_j}) + \eta_i + \epsilon_{ij} > 0 \\ 0 \text{ otherwise.} \end{cases}$$

From this expression it becomes clear that the variables used in estimation are the differences between the attribute levels of scenario B and scenario A. For example DAM is defined as the maximum level of loss in scenario B *minus* the maximum level of loss in scenario A (see table 2).

4.3 Explanatory variables

Table 2 shows the variables used and their labels. The product attributes were already explained in section 3. Instead of price, the outlay on electricity was used as an explanatory variable. In this way, an increase in outlay (occasioned by a higher price) can be interpreted as a reduction of disposable income. Of course, this holds only if outlay and price move in fixed proportions, i.e. if the quantity of power consumed stays constant. Since price elasticities of the household demand for electricity are low in Switzerland (Bonomo, Filippini and Zweifel 1998), this assumption is justifiable.

Label	**Definition**	**Mean**	**Std.Dev.**
WASTE	=-1:no problems w. waste disposal	-0.476	0.500
BLACKO	Blackout	0.479	0.500
DAM	Loss in CHF bn.	-128.310	81.277
COV	Insurance coverage	42.880	37.560
P	outlay on electricity	260.398	376.655
DAM2	DAM^2	-28256.030	16336.960
COV2	COV^2	3334.892	4058.592
P2	P^2	1019087.000	51089767.000
BLACKOP	blackouts·outlay	580.458	981.833
WASTEP	waste·outlay	-316.995	843.406
DAMP	loss·outlay	-104770.800	140571.300
COVP	coverage·outlay	52876.310	77898.460
DAMCOV	loss·coverage	3217.482	5738.957
DAMWST	loss·waste	-169.752	62.457

continued...

Label	Definition	Mean	Std.Dev.
DAMBLA	loss·blackouts	34.709	63.833
COVWST	coverage·waste	20.738	33.267
COVBLA	coverage·blackouts	22.633	35.385
HIGH	accident probability high[a]	0.704	0.456
HIGHP	HIGH·outlay	181.472	347.793
HIGHP2	HIGH·outlay^2	746116.400	4946851.000
EDM	medium level of education[b]	0.825	0.380
EDH	high level of education[c]	0.079	0.267
EDMP	EDM·outlay	206.751	300.625
EDMP2	EDM·outlay^2	645225.400	2252081.000
EDHP	EDH·outlay	35.281	259.240
EDHP2	EDH·outlay^2	334052.200	4635214.000
AGE	age	43.706	13.912
AGEP	AGE·outlay	11492.580	17600.630
AGEP2	AGE·outlay^2	4.54e+07	2.32e+08
SEXM	gender[d]	0.504	0.500
SEXMP	gender·outlay	136.013	325.082
SEXMP2	gender·outlay^2	604057.200	4691084.000
C	constant	1.000	0.000

Note: Attribute values shown are differences between alternative (B) and status quo (A) and may therefore be negative

[a)] Dummy varible, = 1 if subjective probability of accident is higher than that of experts

[b)] Vocational school, community college, technical college

[c)] University for applied sciences, university

[d)] 0 = female, 1 = male

Table 2: Variables used in estimation.

Product attributes appear in linear, quadratic and mixed form. The dummy variables for BLACKO and WASTE cannot be squared because of multicollinearity.

4.4 Estimation results

4.4.1 General findings

The model in section 4.2 was estimated using a random effects probit specification. The estimation results for the approximated utility function are displayed in table 3. This estimation excludes mixed terms involving income in order to be able to use the full sample.

The significantly positive value of $\rho = 0.56$ shows that a random-effects specification is appropriate as 56 percent of the variance of the error term can be attributed to individual-specific effects. The linear forms of four out of five product attributes have the expected sign; DAM is the only (and insignificant) exception. Moreover, for damages exceeding the status quo by

	df/dx[a]	Coefficient	Std.Dev.	z
BLACKO	-0.08049871	-0.2205927 *	0.1192424	-1.850
WASTE	0.25848292	-0.6598493 **	0.1186114	-5.563
DAM	0.00082439	0.0021668	0.0016999	1.275
COV	0.00618963	0.0162685 **	0.0033763	4.818
P	-0.00358838	-0.0094315 **	0.0015073	-6.257
DAM2	-0.0000103	-0.0000271 **	8.09e-06	-3.348
COV2	-0.00003345	-0.0000879 **	0.0000281	-3.124
P2	8.114e-07	2.13e-06 **	5.13e-07	4.157
BLACKOP	-0.00001751	-0.000046	0.0000639	-0.720
WASTEP	-0.0000125	-0.0000329	0.0000586	-0.561
DAMP	-3.366e-07	-8.85e-07 **	3.91e-07	-2.264
COVP	-7.092e-07	-1.86e-06 **	7.45e-07	-2.503
DAMCOV	0.00001356	0.0000357 **	0.0000107	3.321
DAMWST	0.00045898	0.0012064	0.0007812	1.544
DAMBLA	-0.00013523	-0.0003554	0.000725	-0.490
COVABF	0.00052263	0.0013737	0.0015513	0.886
COVWST	-0.00137768	-0.003621 **	0.0016469	-2.199
HIGHP	0.00027532	0.0007236 **	0.0003355	2.157
HIGHP2	-6.745e-08	-1.77e-07 **	5.58e-08	-3.178
EDMP	0.0023652	0.0062166 **	0.0013788	4.509
EDMP2	-6.464e-07	-1.70e-06 **	4.93e-07	-3.448
EDHP	0.00314532	0.008267 **	0.0014456	5.719
EDHP2	-7.836e-07	-2.06e-06 **	4.97e-07	-4.147
AGEP	2.621e-06	6.89e-06	0.0000118	0.586
AGEP2	-1.855e-09	-4.88e-09 *	2.58e-09	-1.887
SEXMP	-0.00063002	-0.0016559 **	0.0004084	-4.055
SEXMP2	1.530e-07	4.02e-07 **	9.55e-08	4.212
C	0.08343199	0.2192885 *	0.1326647	1.653

*(**): statistically significant on a 10%(5%) level.
$\rho = 0.5643335$
$\sigma_\eta = 1.1398127$
$4'119$ observations (375 individuals)
Log likelihood: -1948.9473
Log likelihood (constant only): -2337.5593

[a]) Probability differential relative to status quo.

Table 3: Estimation of utility function, with income excluded.

US$ 56 bn. or more, the negative sign of DAM2 changes the overall impact from positive to negative (neglecting mixed terms). Therefore, at least in a range of maximum losses considered realistic by experts, a further increase of maximum loss lowers respondent's utility, ceteris paribus. The strong estimated influence of the waste disposal attribute confirms the results of the two pretests.

The second column of table 3 shows the probability differential compared to the status quo for a person with median characteristcs. For example, the value of 0.26 for waste disposal (WASTE) can be interpreted as the increase in the probability of such a median person preferring the scenario

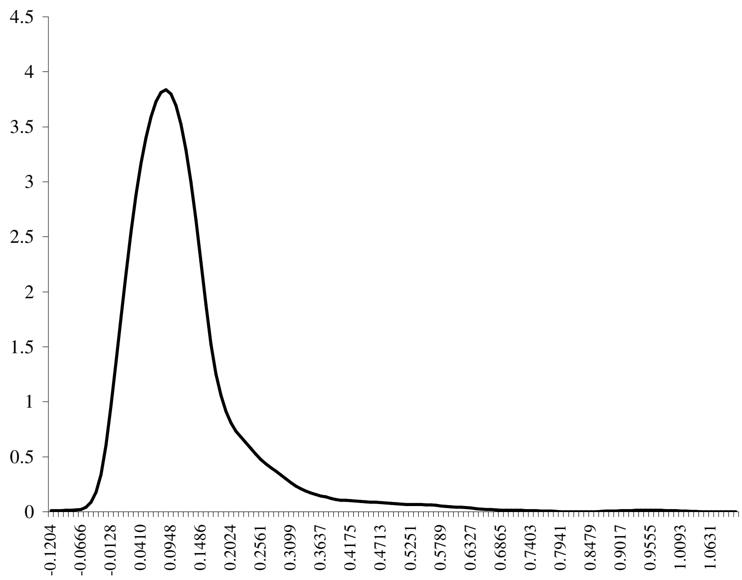

Figure 3: Density of MWP in cents/kwh. DAM = CHF 100 bn. (US$ 65 bn.), WASTE=1, BLACKO=0 and COV=1%. (Epanechnikov kernel with a bandwidth of 0.66)

that has no unresolved waste disposal problems (WASTE=0) over a scenario with unresolved waste disposal problems (WASTE=1). On the other hand, the probability of preferring a power type is reduced by more blackouts (BLACKO=1) by a mere 8 percentage points compared to less blackouts (BLACKO=0) and hence better reliability.

Most importantly however, additional insurance coverage (COV) has a positive effect on utility. If coverage is increased to 100 percent, then the probability of the corresponding power type being preferred increases by an estimated 60 percentage points. Finally, electricity outlay has the expected negative effect on utility despite the positive sign of P2. This is because the socioeconomic interaction terms reinforce without exception the negative marginal utility of electricity outlay.

4.4.2 Calculation of MWP for financial security

The marginal willingness to pay (MWP) for additional coverage is given by

$$MWP = \frac{\partial \hat{U}/\partial COV}{\partial \hat{U}/\partial P} \ ,$$

with P defined as outlay on electricity so that $-\partial \hat{U}/\partial P$ is the estimated marginal utility of disposable income. The ratio between the marginal utility of coverage and the marginal utility of income defines the MWP for

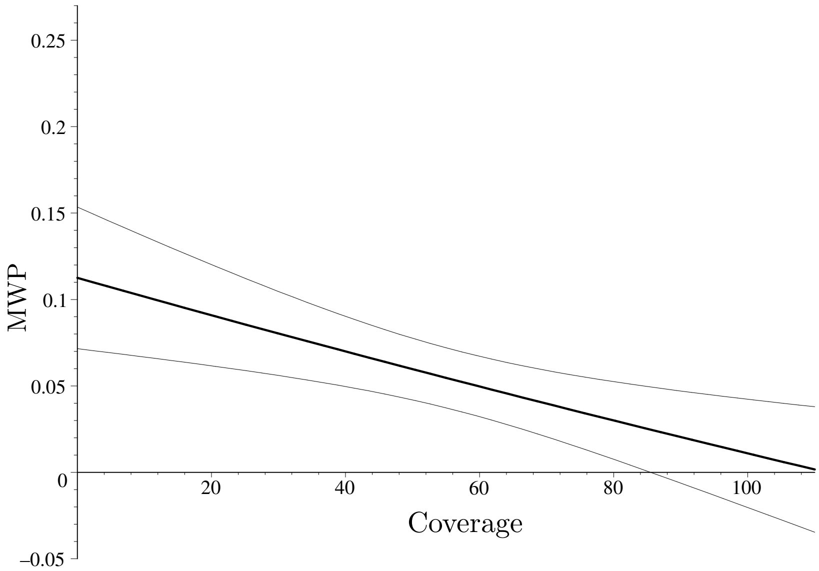

Figure 4: MWP in cents/kwh including 95 percent confidence intervals; 44 year old woman, EDM=1, HIGH=1, DAM=100 (US$ 65 bn.), WASTE=1, BLACKO=0, P=840 (US$ 560).

additional financial security through increased insurance coverage. In order to express the MWP in terms of cents per kwh, the quantity of power consumed must be known. This was calculated as the annual outlay devided by the average price of electricity at the household level during the year 1999 (16.2 Rp/kwh, i.e. 11 cents), obtaining

$$\text{MWP[cents/kWh]} := \frac{\text{MWP[US\$/year]} \cdot 100}{\text{Outlay in US\$}/0.11}$$

In order to get an impression of the MWP across the entire sample, the MWP for increased coverage was calculated for each person based on his or her specific socioeconomic characteristics and a power type which has few blackouts (BLACKO=0), unresolved problems with waste disposal (WASTE=1), a maximum possible loss of CHF 100 bn. (US$ 65 bn.) and initial coverage amounting to a mere 1 percent (COV=1%). The resulting density function is shown in figure 3.

Average MWP is 0.11 cents/kwh, while the median MWP lies at 0.07 cents/kwh. Compared to the average price of 11 cents paid in 1999, this corresponds to one percent of the electricity price. This does not seem excessive a priori, especially when taking the decline of MWP with increasing coverage into account (see figures 4 and 5 below).

In order to check whether MWP values are significantly different from zero, standard errors were calculated, using the delta-method although it may result in an underestimate (see e.g. Polsky, Glick, Willke and Schulman

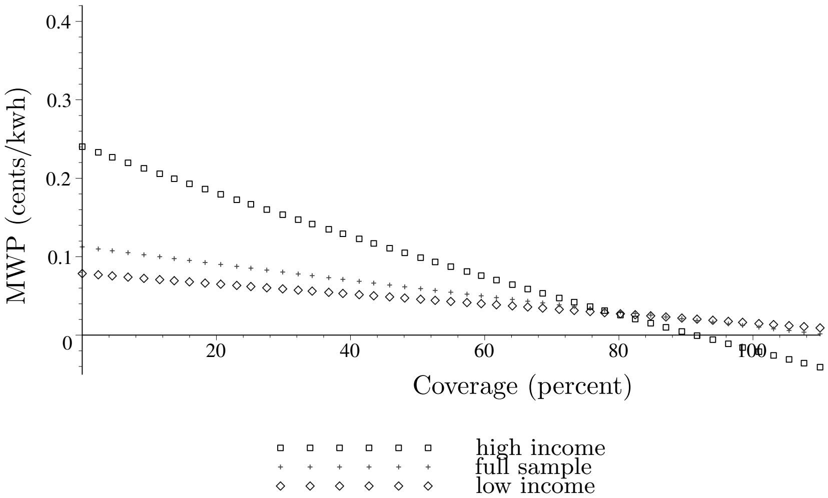

Figure 5: MWP in cents/kWh of a 44 year old woman with EDM=1, HIGH=1 and outlay on electricity of CHF 840 (US$ 560) per year. Maximum loss is CHF 100 bn. (US$ 65 bn.), WASTE=1, BLACKO=0.

(1997) and Telser (2002)). However, the Filler method only works for a simple ratio of coefficients, while bootstrapping would have been too costly.

Figure 4 shows the MWP of a person with median characteristics (woman aged 44 with EDM=1, HIGH=1) along with its 95 percent confidence intervals. Estimated MWP declines, becoming indistinguishable from zero near an initial coverage rate of 84 percent. At a coverage level of 100 percent at the latest, MWP should be zero. However, this restriction was in no way built into the experiment. Figure 4 thus may be considered as providing some limited evidence for the experiment's validity.

4.4.3 Plausibility tests of estimated MWP

A first plausibility test derives from the influence of income on WTP. If financial security is a normal economic good, MWP should be higher than average among individuals with high income. This prediction is borne out in figure 5 in that the high-income subsample displays a higher MWP than the full sample up to an initial coverage of appr. 70 percent. Conversely, the low-income subsample (which includes respondents not revealing their income) lies below the full sample in this range. However, these differences lack statistical significance due to small sample sizes.

Second, due to the income effect, MWP should decline with increasing outlay on electricity. This is indeed the case without exception in both tables 4 and 5. Moreover, MWP again decreases with initial coverage for a given value of electricity outlay, confirming figures 5 and 4.

Comparison of tables 4 and 5 (with maximum loss doubled) shows that

Coverage	Electricity outlay (US$ at 2002 exchange rates)						
(percent)	400	530	670	800	930	1070	1200
0	0.1598	0.1185	0.0936	0.0770	0.0652	0.0563	0.0493
20	0.1297	0.0957	0.0753	0.0617	0.0520	0.0447	0.0390
40	0.1006	0.0738	0.0577	0.0469	0.0392	0.0335	0.0289
60	0.0723	0.0525	0.0405	0.0326	0.0269	0.0226	0.0192
80	0.0450	0.0319	0.0240	0.0187	0.0149	0.0121	0.0098
100	0.0185	0.0119	0.0079	0.0053	0.0033	0.0019	0.0007

Table 4: MWP in cents/kwh of a 44 year old woman with EDM=1, HIGH=1. Maximum loss is CHF 100 bn. (US$ 65 bn.), WASTE=1, BLACKO=0.

Coverage	Electricity outlay (US$ at 2002 exchange rates)						
(percent)	400	530	670	800	930	1070	1200
0	0.1811	0.1346	0.1067	0.0880	0.0747	0.0647	0.0569
20	0.1518	0.1125	0.0889	0.0731	0.0619	0.0534	0.0468
40	0.1234	0.0911	0.0716	0.0587	0.0494	0.0425	0.0370
60	0.0959	0.0703	0.0549	0.0447	0.0373	0.0319	0.0275
80	0.0691	0.0501	0.0387	0.0311	0.0257	0.0215	0.0183
100	0.0431	0.0306	0.0230	0.0179	0.0143	0.0116	0.0095

Table 5: MWP in cents/kwh of a 44 year old woman with EDM=1, HIGH=1. Maximum loss is CHF 200 bn. (US$ 130 bn.), WASTE=1, BLACKO=0.

MWP increases systematically with maximum possible loss. This too corresponds with theoretical considerations if risk aversion is assumed (Chambers and Quiggin 2000, ch. 3).

Finally, under very general conditions, the MWP of a risk averse individual is predicted to increase with increasing probability of an accident. Evaluation of the equation for MWP with regard to all relevant levels of the attributes shows that the MWP of individuals with HIGH=1 (probability of accident is higher than experts' estimates) is indeed greater than with HIGH=0. Thus, an individual having the median characteristics of the sample with HIGH=1 has a MWP that is appr. 0.013 cents/kwh higher, given the combination of electricity attributes in table 4.

4.5 Out of Sample Test

The two performance criteria of an empirical investigation are its reliability and validity (Singleton and Straits 1999). Reliability is concerned with the stability and consistency of the operational definition (here: MWP); validity is concerned with the goodness of fit between the operational definition and the concept that it is supposed to measure (here: valuation of nuclear risks).

Since effective choices cannot be observed and compared with the stated choices in the experiment, it is not possible to check validity directly, i.e. wether estimated MWP for a reduction of financial risk is a good proxi for the valuation of financial consequences of nuclear risks.

However, there are studies suggesting that the 'stated choice' method leads to results that are in line with corresponding hedonistic price estimations (Gegax and Stanley (1997), Louviere, Meyer and Bunch (1999), and Haener, Boxall and Adamowicz (2000)).

As to reliability, an out of sample test can be performed on the 10 percent of observations that were not used for estimation.

The model predicts the probability of choosing the alternate scenario. For a calculated probability of more than 50 percent, the individual is assumed to choose the alternate scenario. It turns out that out of sample, roughly 70 percent of all decisions were predicted correctly. This share has to be compared to the share of correct decisions which would result from a random process. In the sample used for estimation, the alternate scenario was chosen 63 percent of the time. Now, a random process that generates choice of the alternate scenario in 63 percent of all cases and of the status quo scenario in 27 percent would predict correctly in 47 percent of cases, viz. the sum of the probability that the random process predicted the alternative and that the alternative was actually chosen (0.63^2) plus the probability that it predicted the status quo and that the status quo was actually chosen (0.27^2).

The estimated utility model thus serves to increase the share of correct predictions by 23 percentage points over a random process.

5 Conclusions

Measurement of willingness to pay for an increased internalization of the risks emanating from nuclear power plants is important for energy policy. One instrument of internalization is extending coverage provided by mandatory liability insurance for plant operators. For all its popular appeal, such a proposal will face opposition in parliament and by consumers since higher insurance premiums will lead to higher electricity prices.

This study seeks to determine how much Swiss citizens value increased financial security through higher insurance payments in case of an accident, by using the economic concept of marginal willingness to pay for (financial) security.

This concept is implemented by a 'stated choice' experiment, in which respondents decide in favor of or against an alternative to the status quo characterized by several attributes of electricity. These attributes are varied throughout the experiment, in contradistinction to conventional 'contingent valuation' approaches. The relevant attributes were established by means of three pretests and turned out to be price, frequency of blackouts, waste disposal, maximal possible loss in case of an accident, and insurance coverage. The econometric analysis confirms this selection, since all attributes are estimated to be statistically significant arguments of the underlying utility function. Average marginal willingness to pay for an additional percentage point of compensation for losses in excess of the status quo amounts to some 0.11 cents per kwh (median value 0.07 cents), approaching zero when insurance coverage goes towards 100 percent.

Specifically, an increase of mandated liability insurance coverage from today's CHF 0.7 bn. (US$ 0.47 bn.) to CHF 4 bn. (US$ 2.7 bn.) would command a WTP amounting to 0.27 cents/kwh. This can be compared to an estimate of additional cost. In a companion study, a log-logistic density function for nuclear damages (i.e. the loss function for nuclear insurers) was calibrated. According to that study, an increase of liability insurance from today's CHF 0.7 bn. (US$ 0.47 bn.) to CHF 4 bn. (US$ 2.7 bn.) would result in an increase in the price of electricity of 0.008 cents/kwh (Zweifel and Umbricht 2002, table 4.16). Therefore, quintuplicating current insurance coverage could lead to a welfare gain for the majority of Swiss citizens.

This proposition has to be qualified in several ways. On the cost side, the choice of the distribution law can be criticized. Indeed, a different choice (Gamma e.g.) would entail somewhat changed marginal cost estimates. On the benefits side, one has to accept that no thought experiment can simulate the actual decision environment completely. In particular there is no guarantee that participants take described damages seriously and do not speculate on the government providing financial assistance to victims in case of a major accident[1]. On the other hand, estimated values of marginal willingness to pay do exhibit theoretically plausible variations in several dimensions, thus providing a measure of support for the validity of the experiment.

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[1] In fact it is almost certain that the government will step in, as recent much less severe events have shown (e.g. the bailout of Swiss Airlines Ltd in 2002).

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